Constellation-X RGS spectral resolution / effective area tradeoff issue

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- ALS synchrotron measurements from July of MIT fabricated grating test rulings: in-plane grating (IPG) from 1997 and new off-plane grating (OPG) master & replica.

- these are significant because these constitute the first measured **efficiency curves** in multiple orders of candidate grating technology, for a representative configuration (*fixed incidence angle)* over the RGS passband (10-50, 10-70Å).

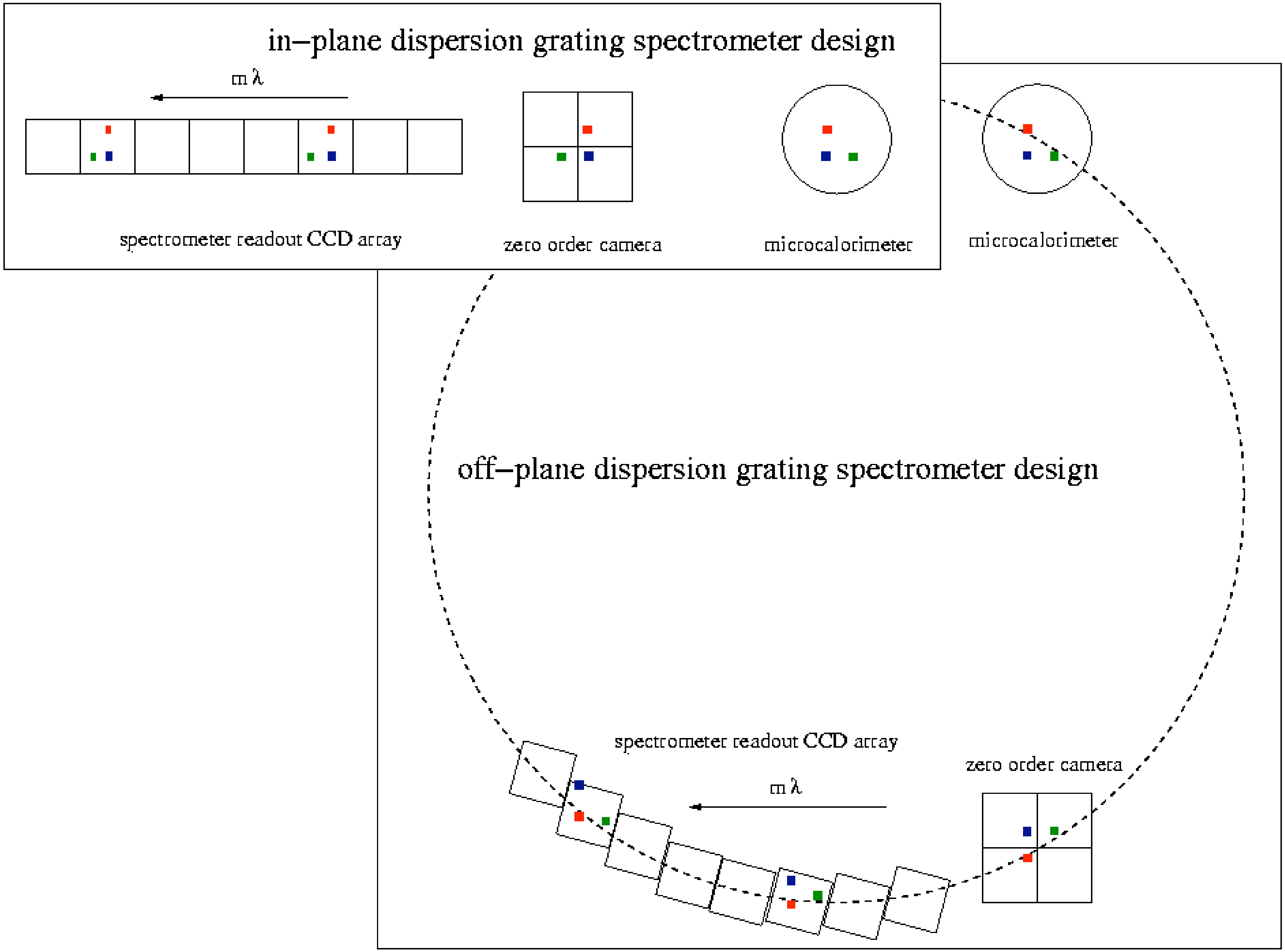
- comparisons to simplistic scalar diffraction theory and how efficiency curves are expected to change as the ruling density (and blaze angle) is varied.

- updated ray trace calculations to model use of *identical* grating subassembly modules throughout the RGA.

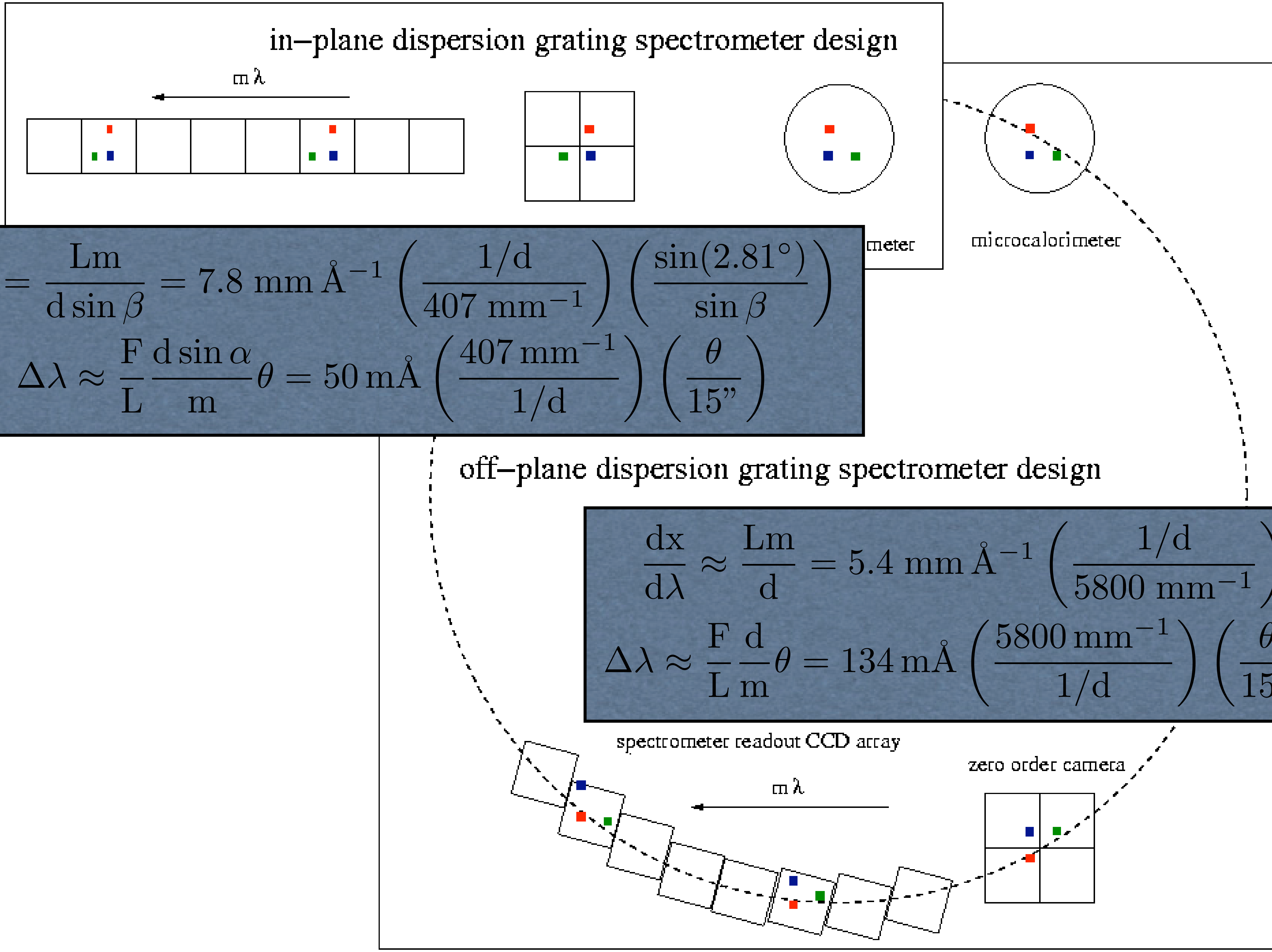
- how well does "scalloping" the PSF work, in the case of the OPG RGS?

- effective area vs. resolving power ..

focal plane mapping of the grating designs



focal plane mapping of the grating designs



$$\frac{\mathrm{dx}}{\mathrm{d}\lambda} = \frac{\mathrm{Lm}}{\mathrm{d}\sin\beta} = 7.8\ \mathrm{mm}\ \mathrm{\AA}^{-1}\left(\frac{1/\mathrm{d}}{407\ \mathrm{mm}^{-1}}\right)\left(\frac{\sin(2.81^\circ)}{\sin\beta}\right)$$

$$\Delta\lambda \approx \frac{\mathrm{F}}{\mathrm{L}}\frac{\mathrm{d}\sin\alpha}{\mathrm{m}}\theta = 50\,\mathrm{m\AA}\left(\frac{407\,\mathrm{mm}^{-1}}{1/\mathrm{d}}\right)\left(\frac{\theta}{15"}\right)$$

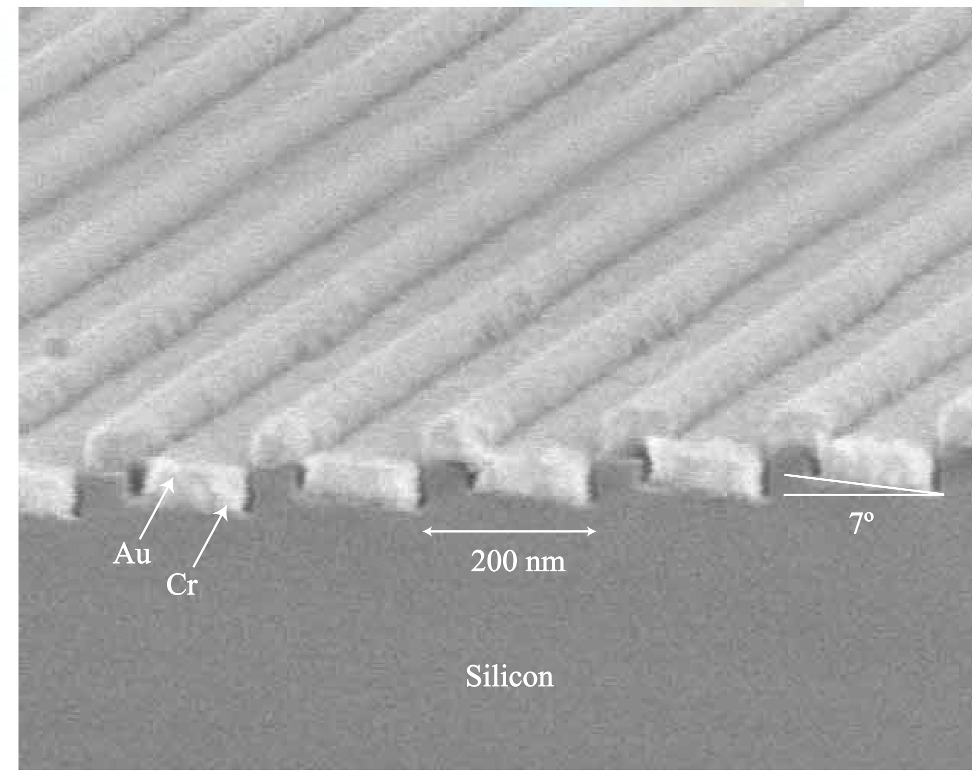
$$\frac{\mathrm{dx}}{\mathrm{d}\lambda} \approx \frac{\mathrm{Lm}}{\mathrm{d}} = 5.4\ \mathrm{mm}\ \mathrm{\AA}^{-1}\left(\frac{1/\mathrm{d}}{5800\ \mathrm{mm}^{-1}}\right)$$

$$\Delta\lambda \approx \frac{\mathrm{F}}{\mathrm{L}}\frac{\mathrm{d}}{\mathrm{m}}\theta = 134\,\mathrm{m\AA}\left(\frac{5800\,\mathrm{mm}^{-1}}{1/\mathrm{d}}\right)\left(\frac{\theta}{15"}\right)$$

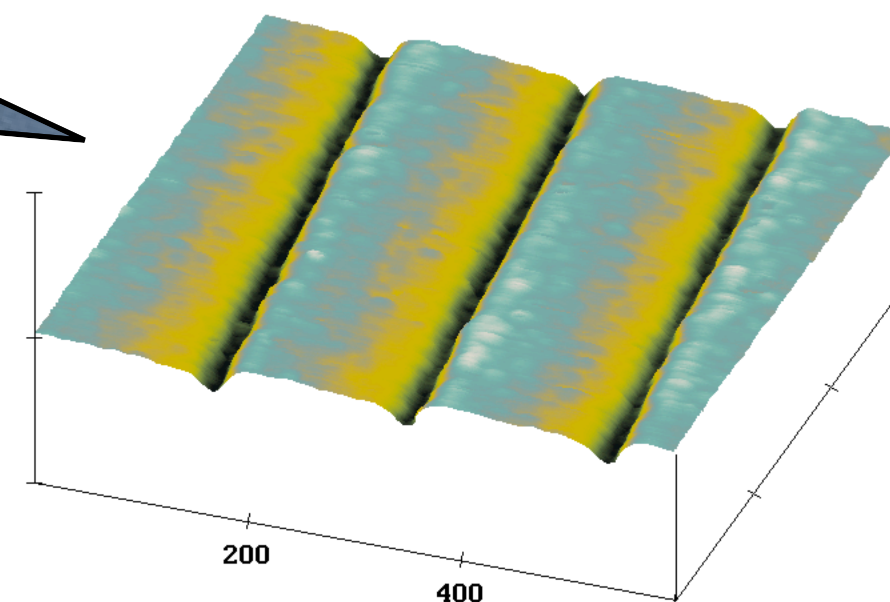
Alignment values for the efficiency measurements:

MIT IPG: (1/d = 580 l/mm, facet angle 0.7°, 50Å Cr + 200Å Au)
alpha (incidence angle) = 1.62°
wavelength range: 10-50 Å
detector scan range: 2 to 10°

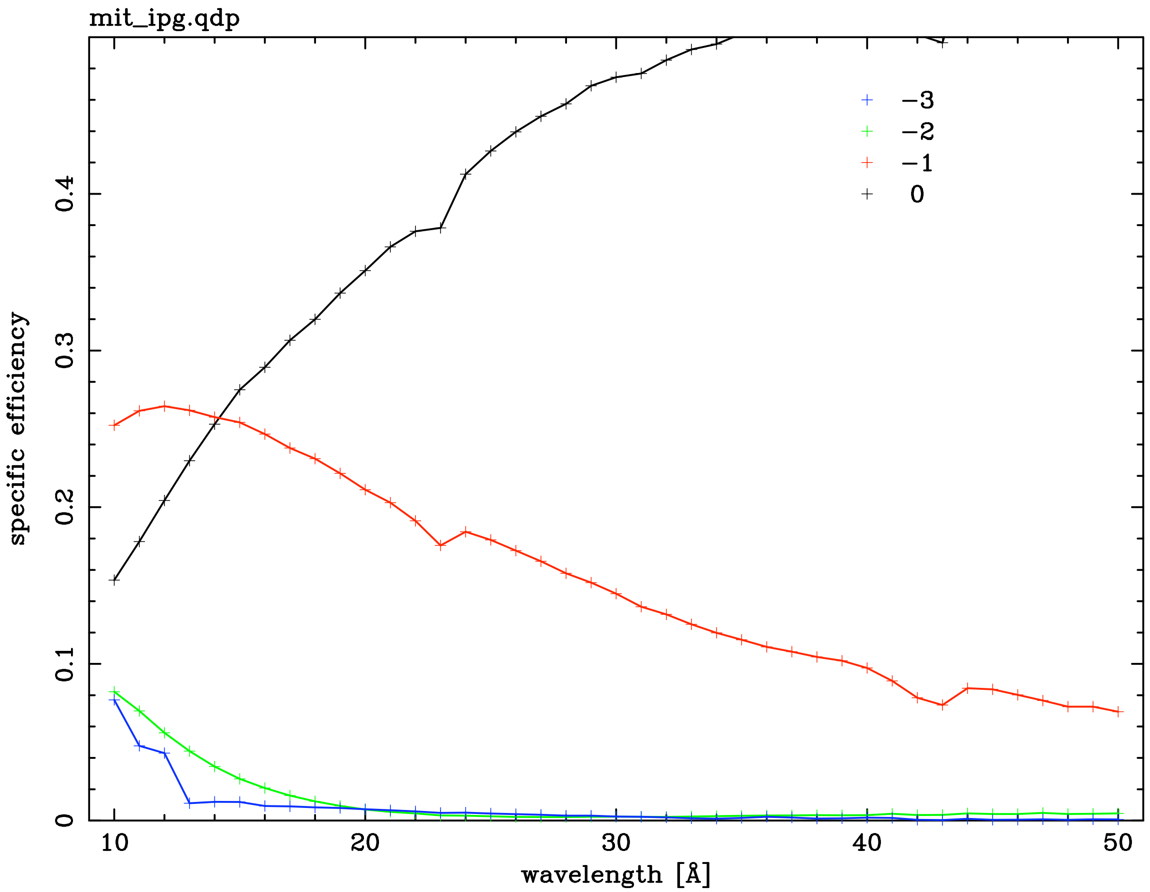
MIT OPG 40: (1/d = 5000 l/mm, facet angle nom. 7°, Si + 50Å Cr + 400Å Au)
gamma (incidence angle against groove) = 1.84°
alpha (azimuth of grating normal) = 20°
wavelength range: 10 to 70 Å
detector scan range: -1° to 3Å

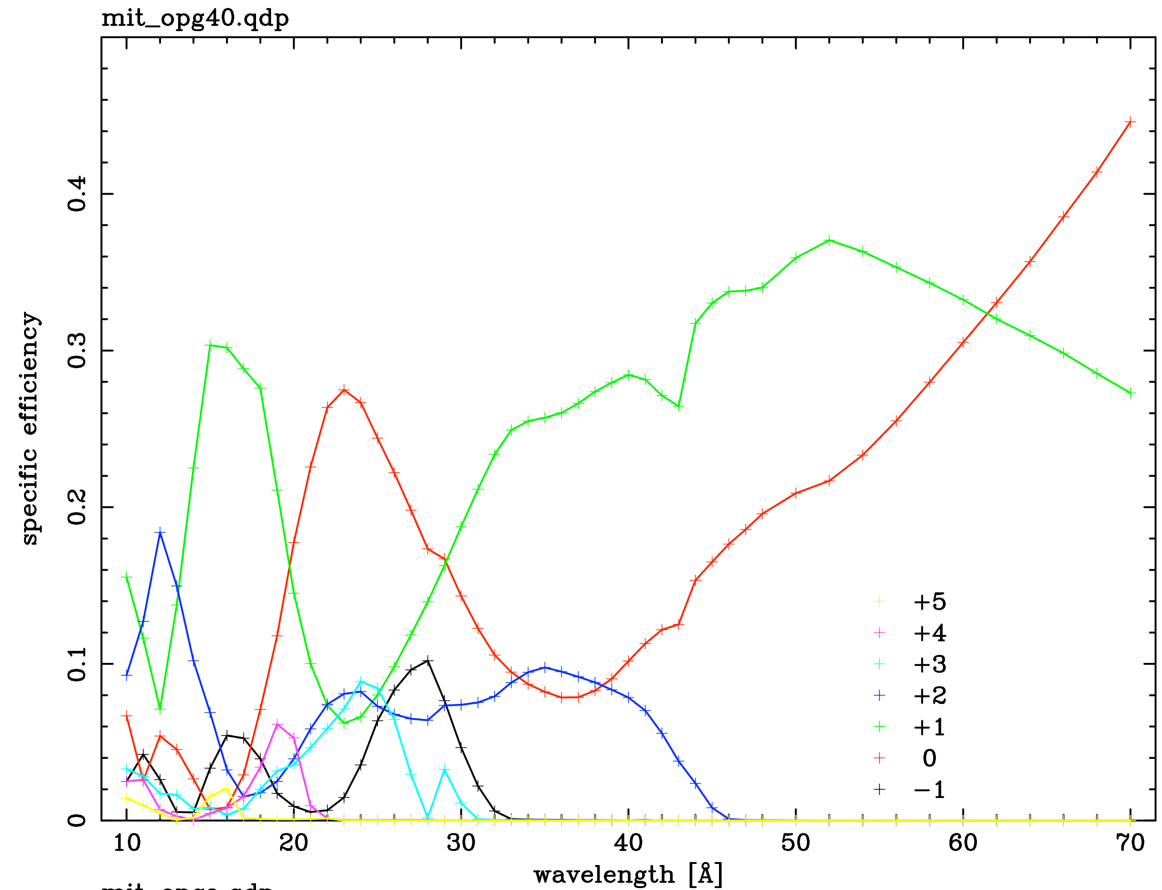


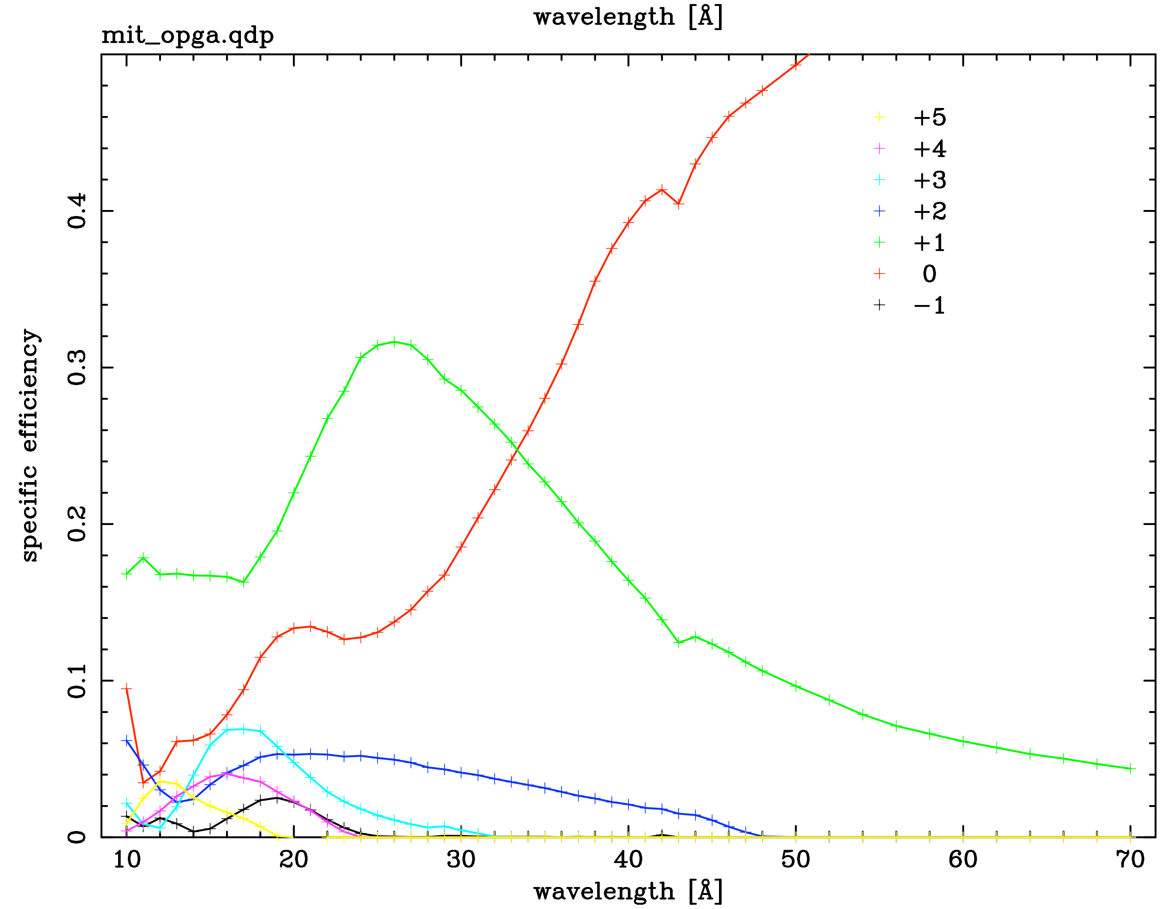
MIT OPG replica "A": (1/d = 5000 l/mm, facet angle 7°, glass + 50Å Cr + 400Å Au)
gamma (incidence angle against groove) = 2.0°
alpha (azimuth of grating normal) = 30°
wavelength range: 10 to 70 Å
detector scan range: -1° to 3Å



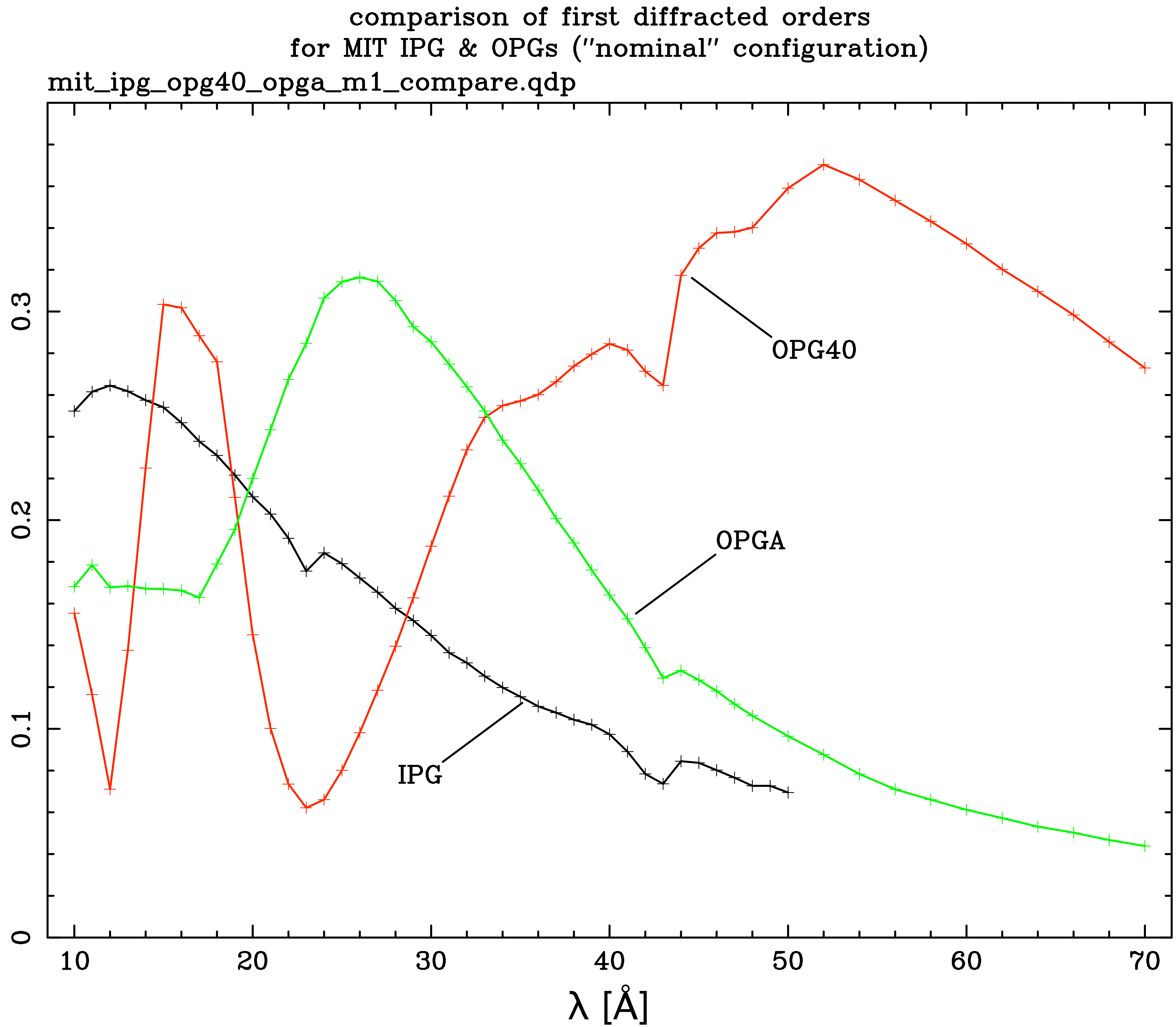
grating efficiency measurements



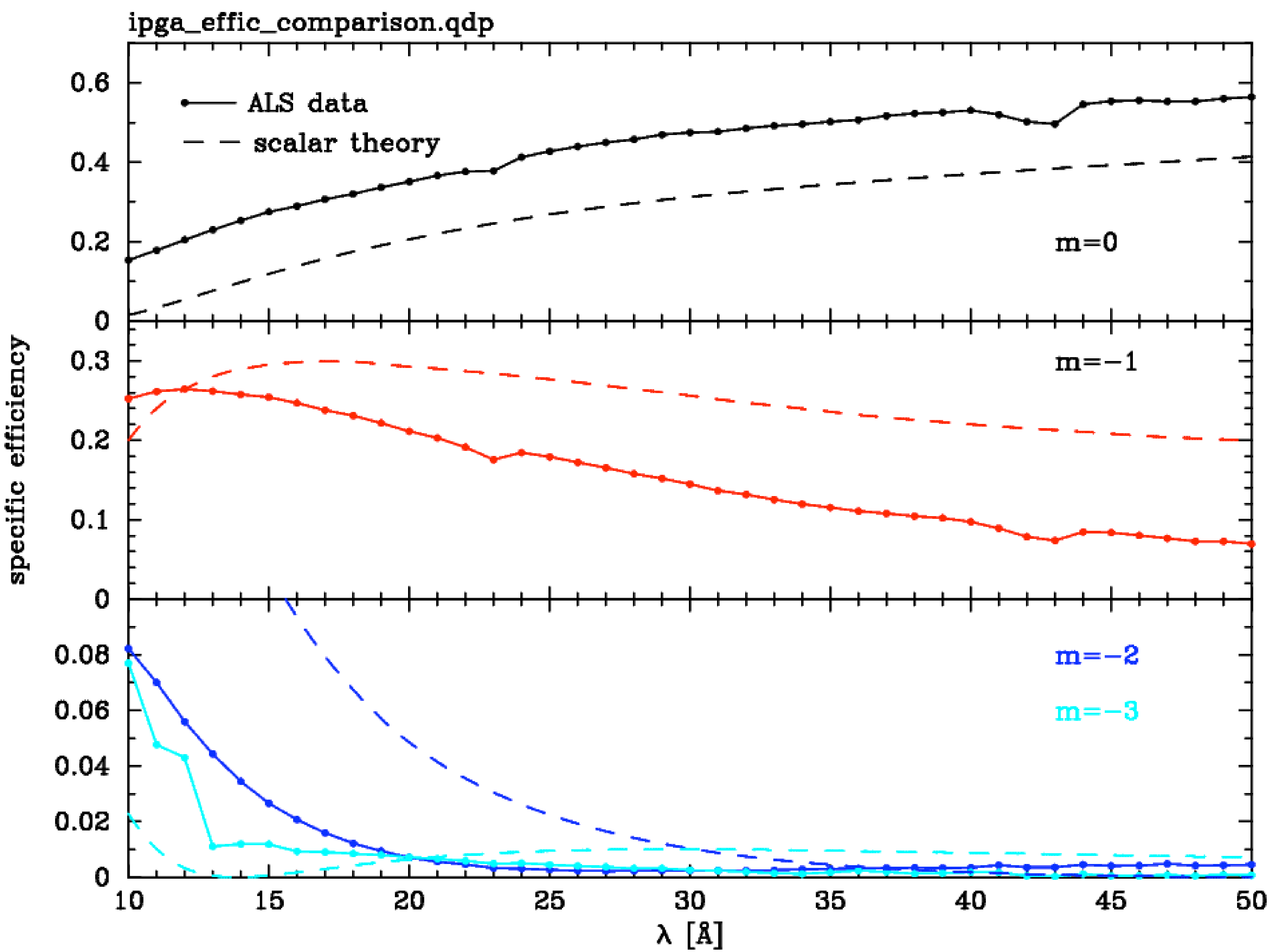




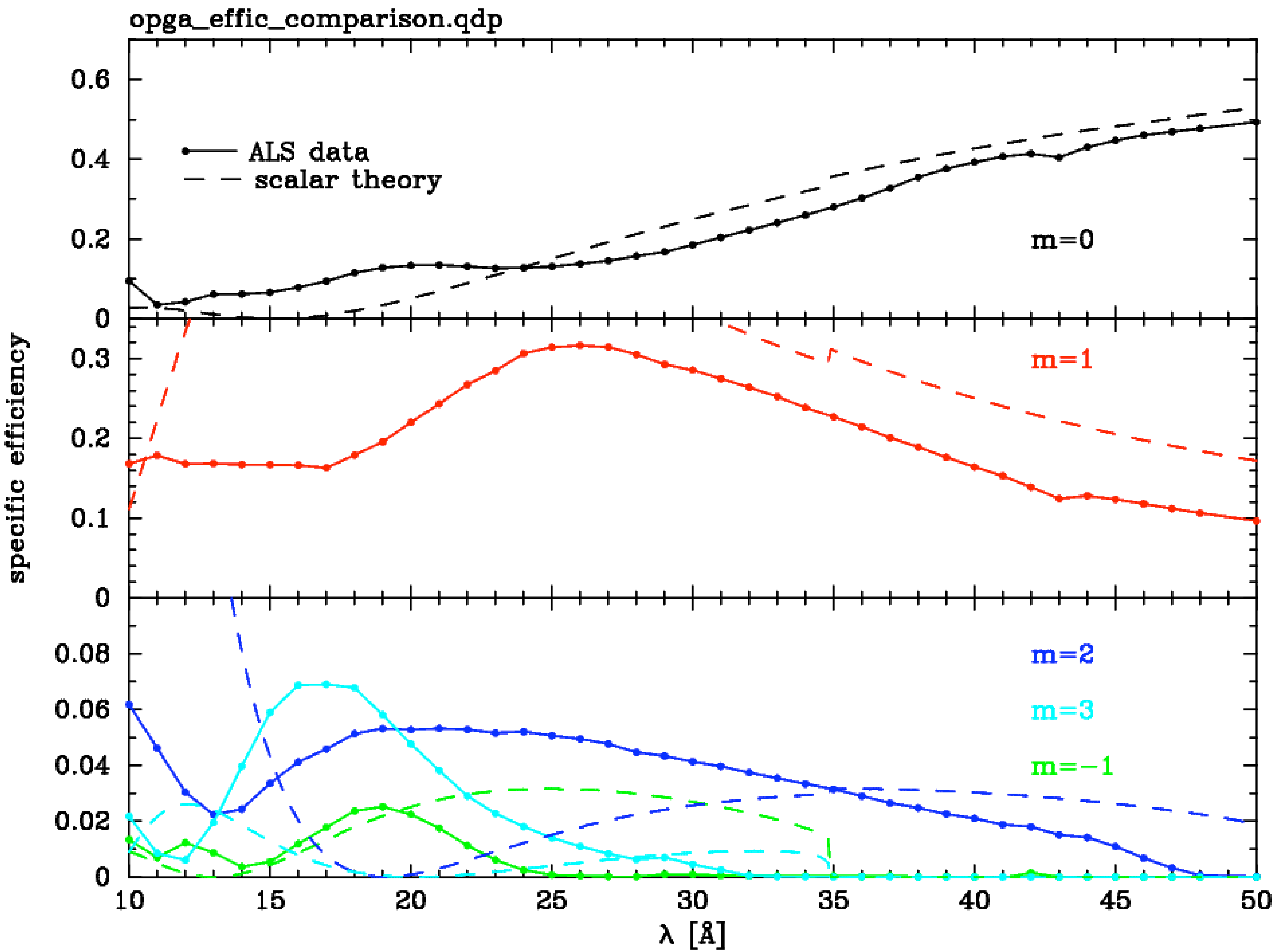
grating efficiency measurements



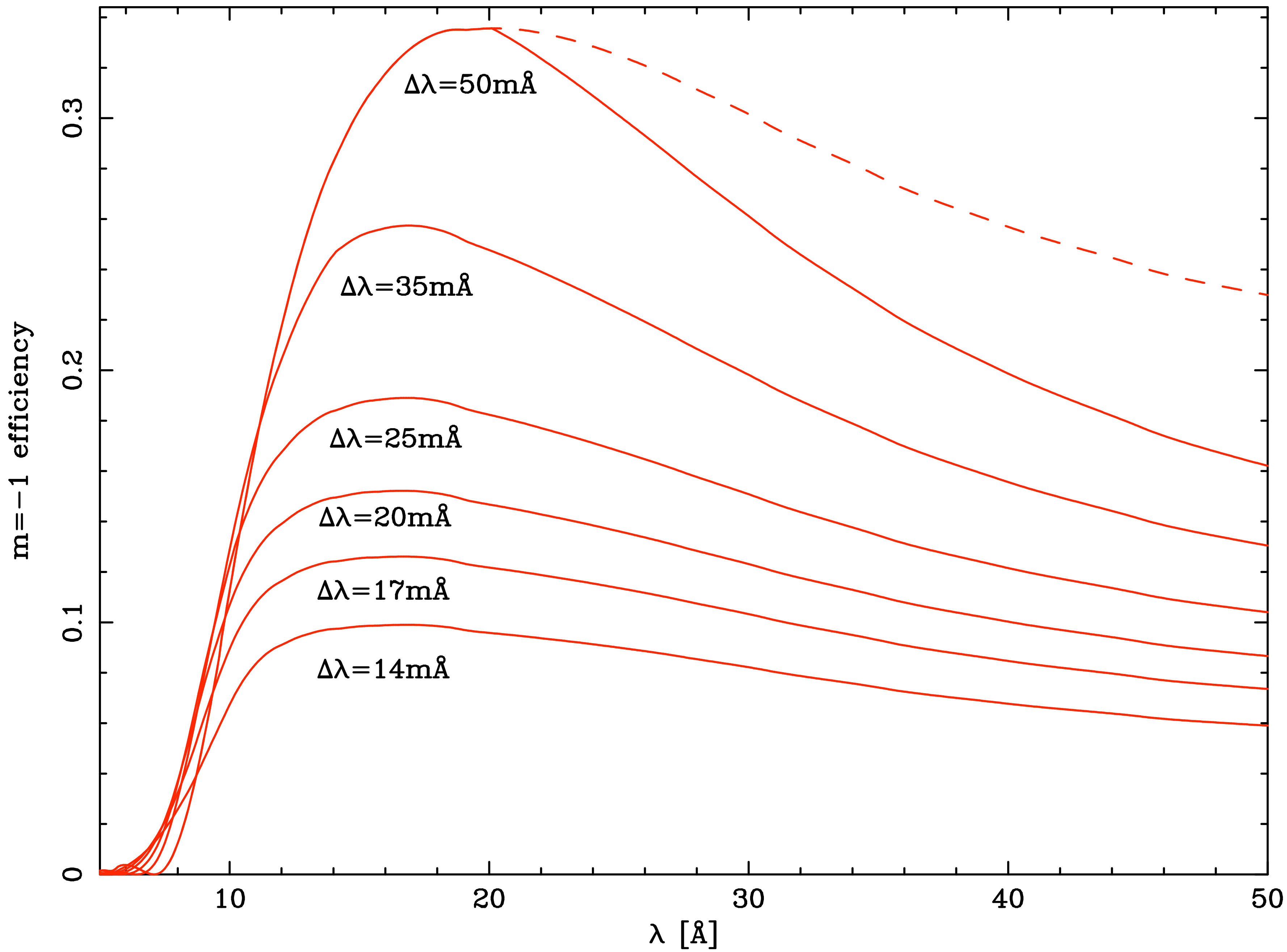
Comparison to scalar diffraction theory: IPG



Comparison to scalar diffraction theory: OPG “A”



IPG Scalar diffraction predictions for altering 1/d (including RGA self-vignetting)



choose your SXT PSF

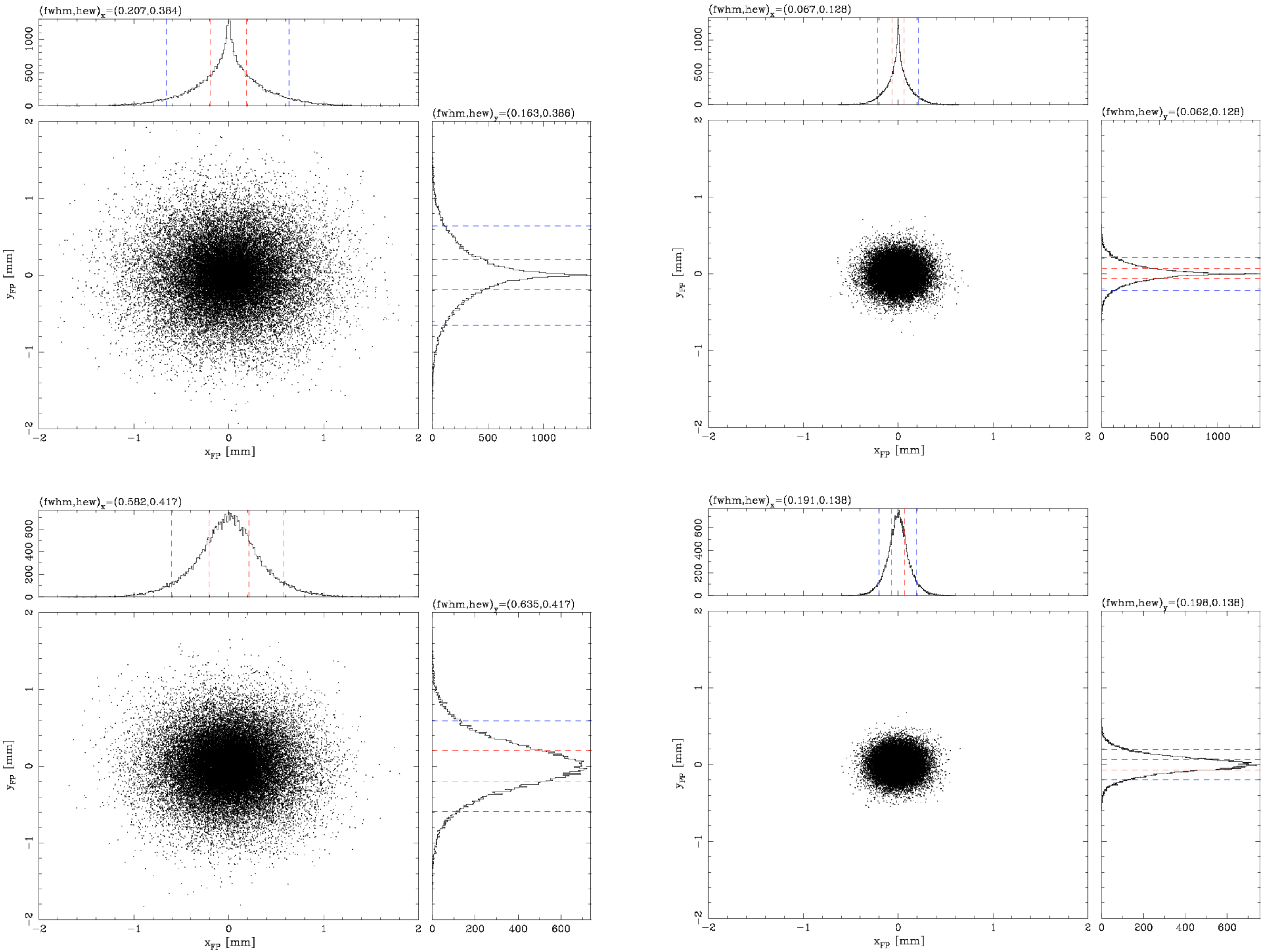


Figure errors only
“FE only”

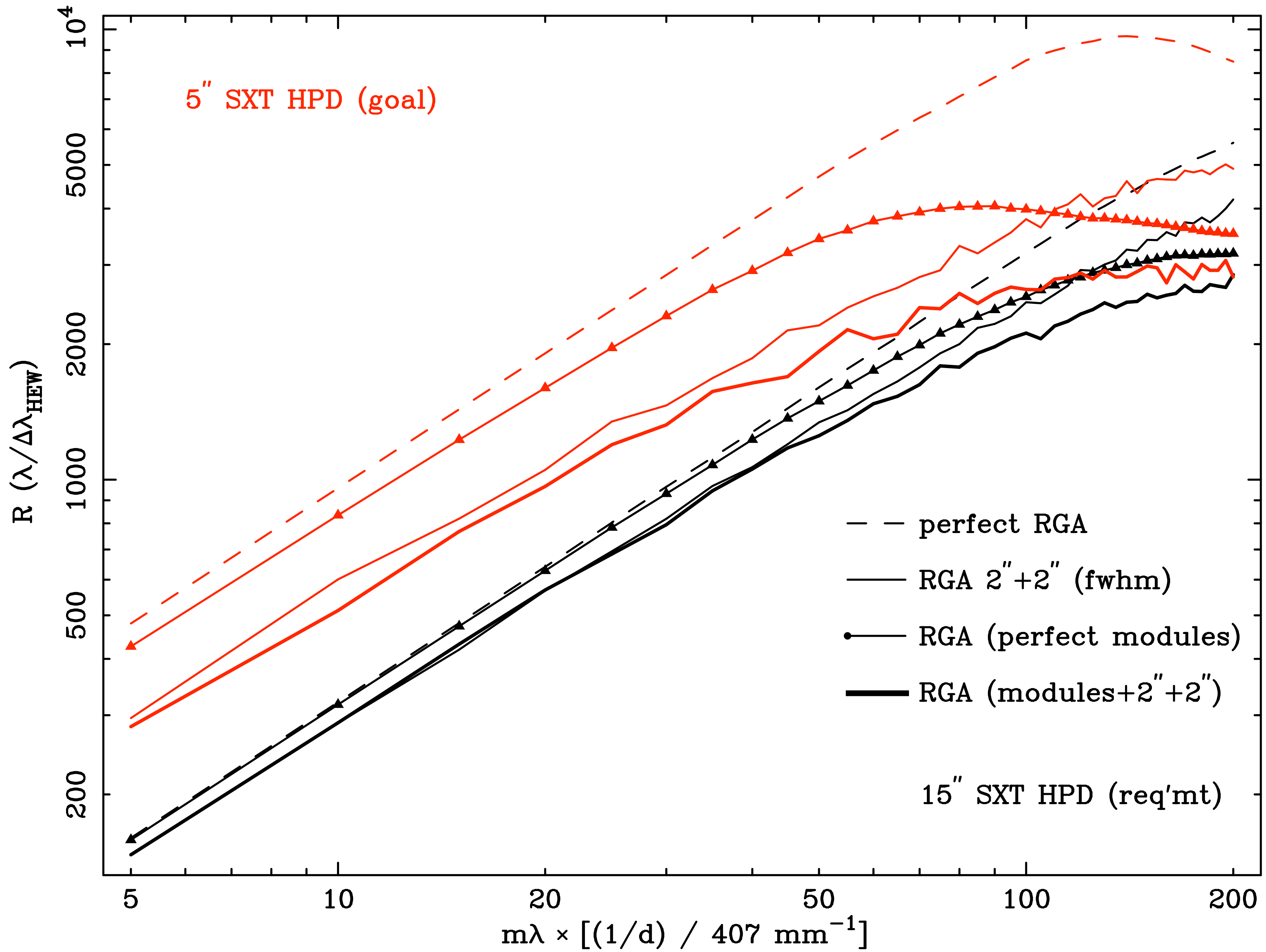
Figure & alignment errors per
SXT error budget “FE+AE”

req’mt (15” HPD)

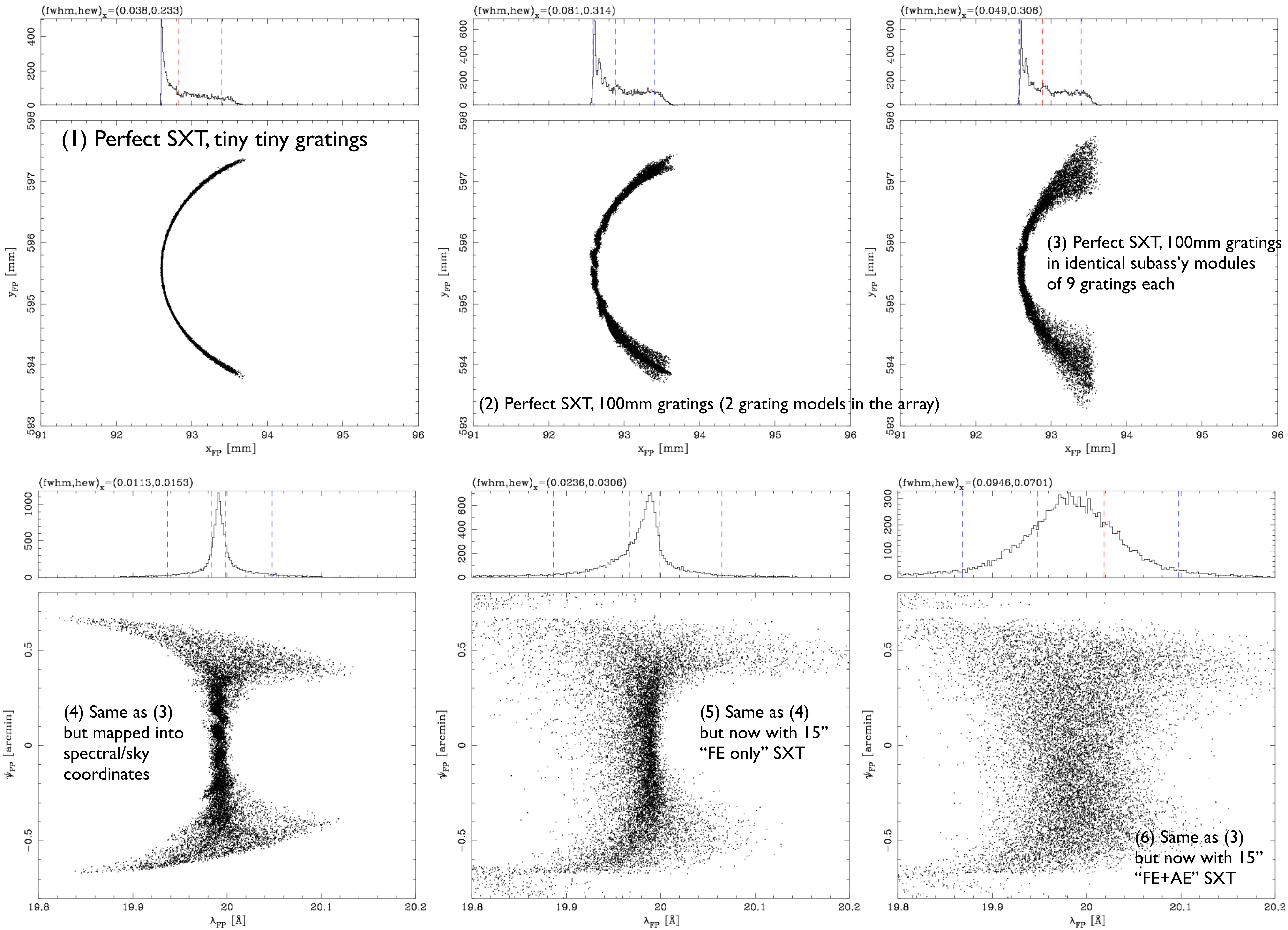
“goal” (5” HPD) - left scaled by 1/3

l/d is a “free” parameter and so is the RFC detector length..

using “FE+AE” SXT PSF



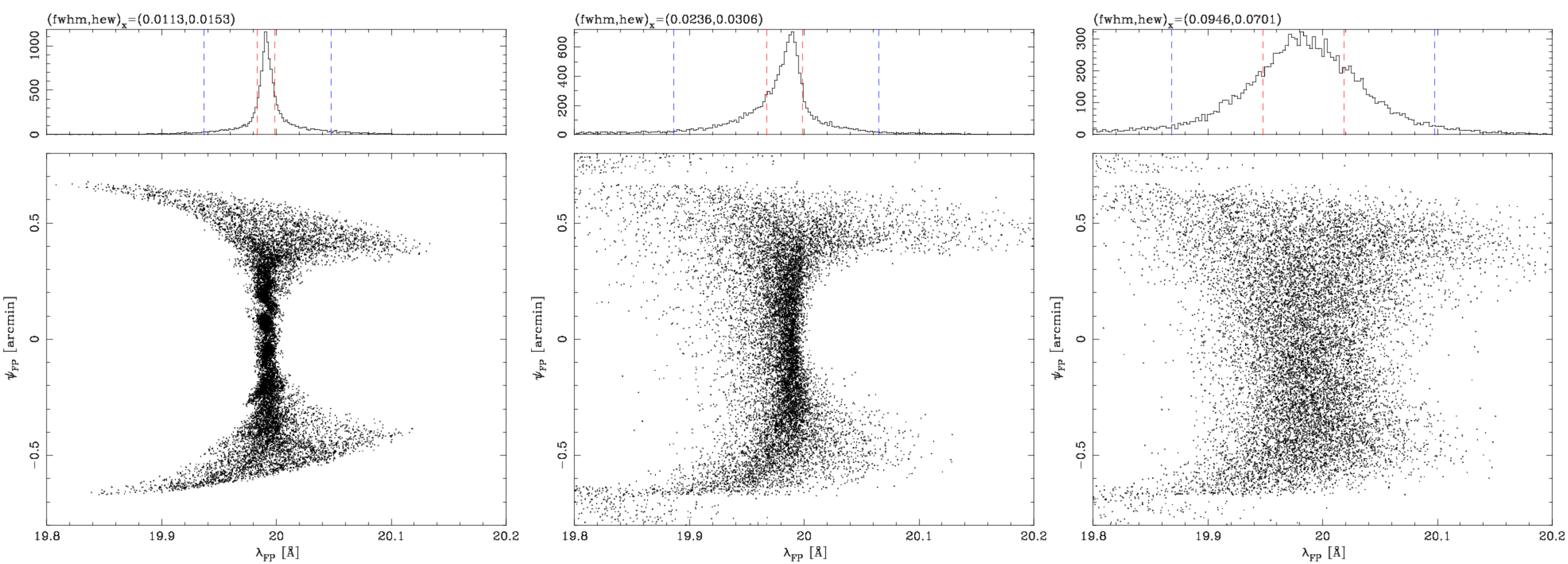
Resolving power increases as the IPG ruling density and RFC readout length are both increased...
Resolving power can be increased by about 4 if the readout length (0 to 50Å) is increased from 381 to 931 mm.
(the background also increases by a similar factor)



(fwhm,hew)x=(0.038,0.233)
(fwhm,hew)x=(0.081,0.314)
(fwhm,hew)x=(0.049,0.306)
(1) Perfect SXT, tiny tiny gratings
(2) Perfect SXT, 100mm gratings (2 grating models in the array)
(3) Perfect SXT, 100mm gratings in identical subass'y modules of 9 gratings each
yFP [mm]
xFP [mm]
(fwhm,hew)x=(0.0113,0.0153)
(fwhm,hew)x=(0.0236,0.0306)
(fwhm,hew)x=(0.0946,0.0701)
(4) Same as (3) but mapped into spectral/sky coordinates
(5) Same as (4) but now with 15" "FE only" SXT
(6) Same as (3) but now with 15" "FE+AE" SXT
ψFP [arcmin]
λFP [Å]

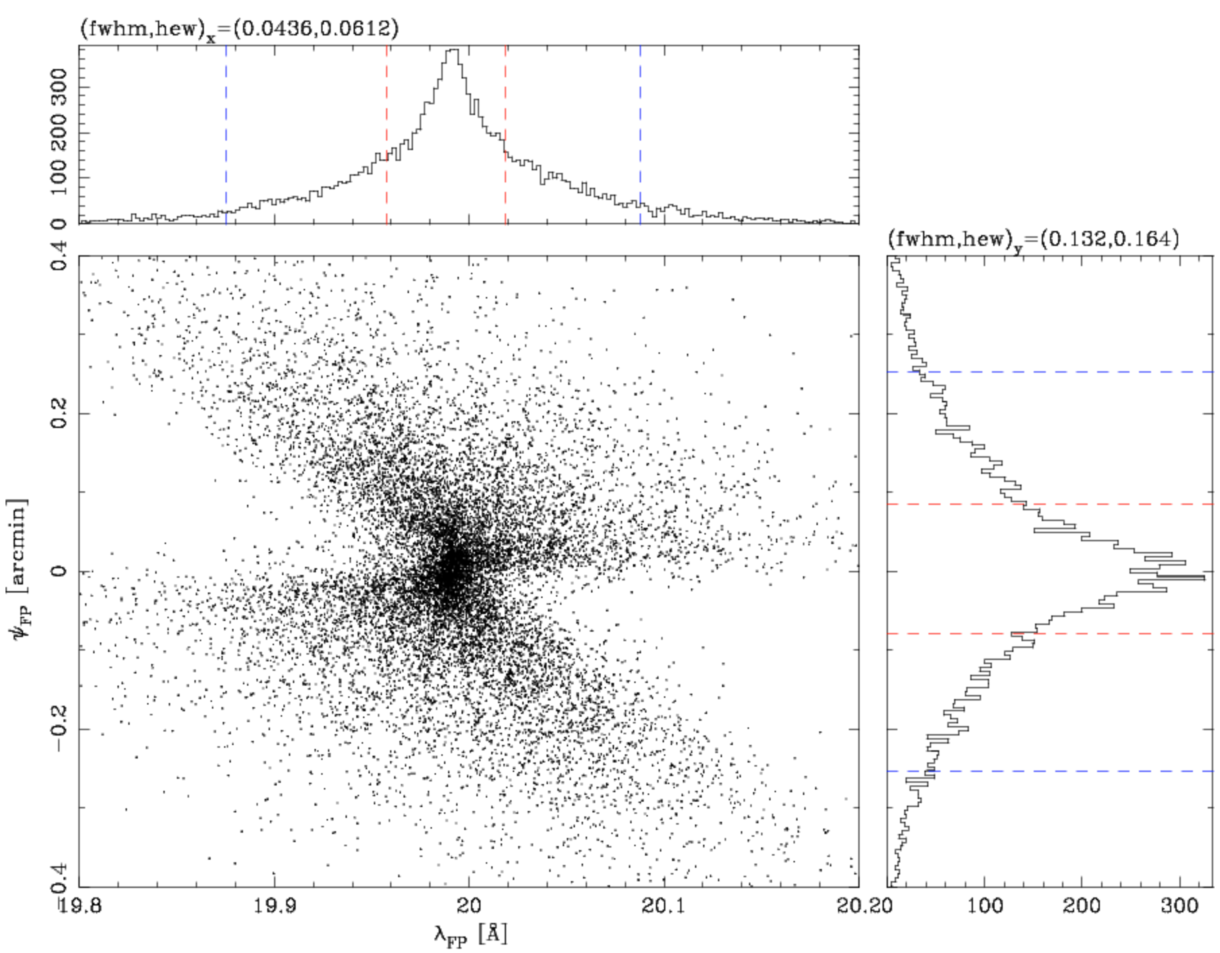
$\Delta\lambda_{HEW}$: 15→30→70mÅ

(with grating misalignments *<u>not included</u>* yet)

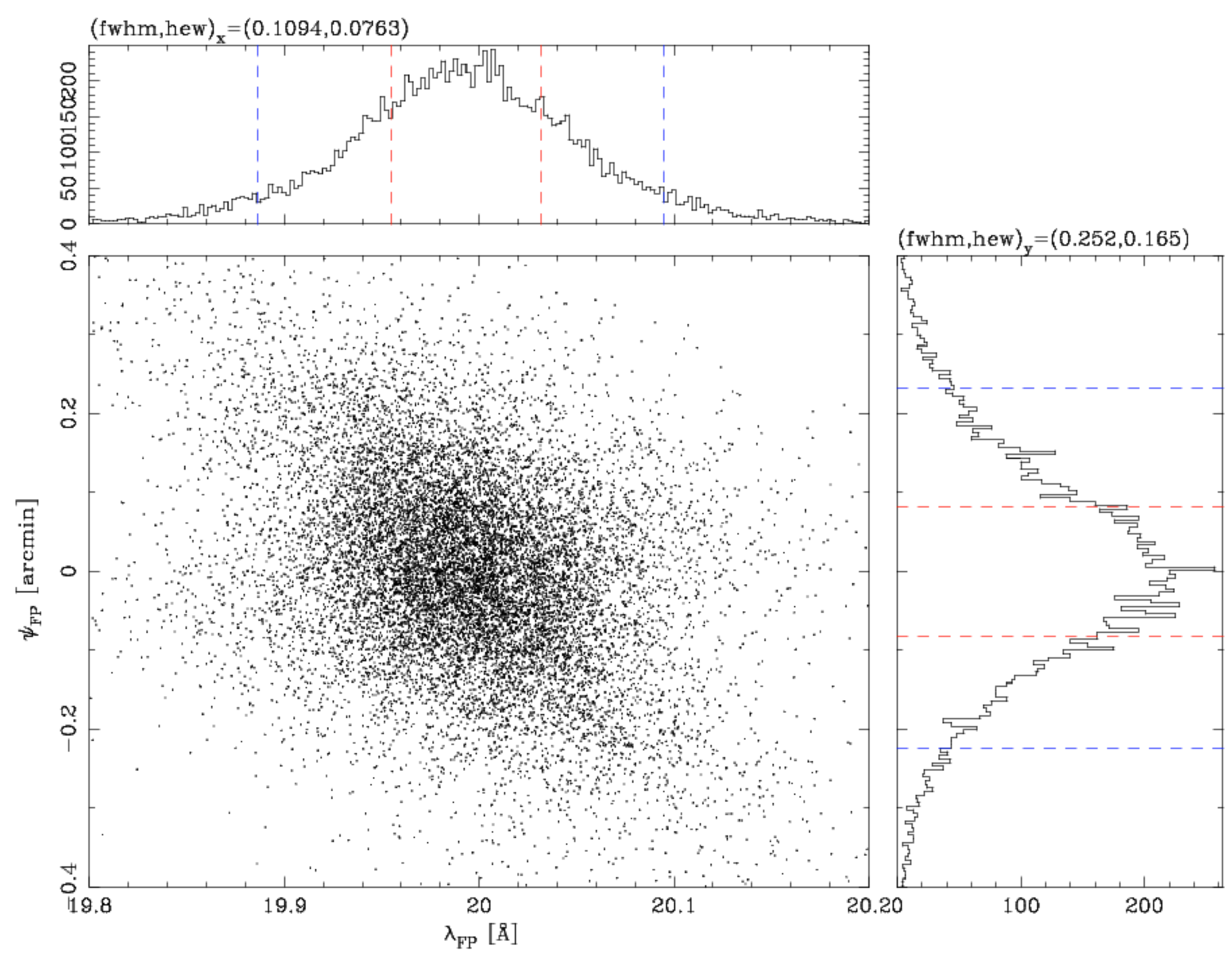


RGS resolving power is only moderately better with 2mm scalloped PSF than with no scalloping at all:

15” HPD “FE only” SXT



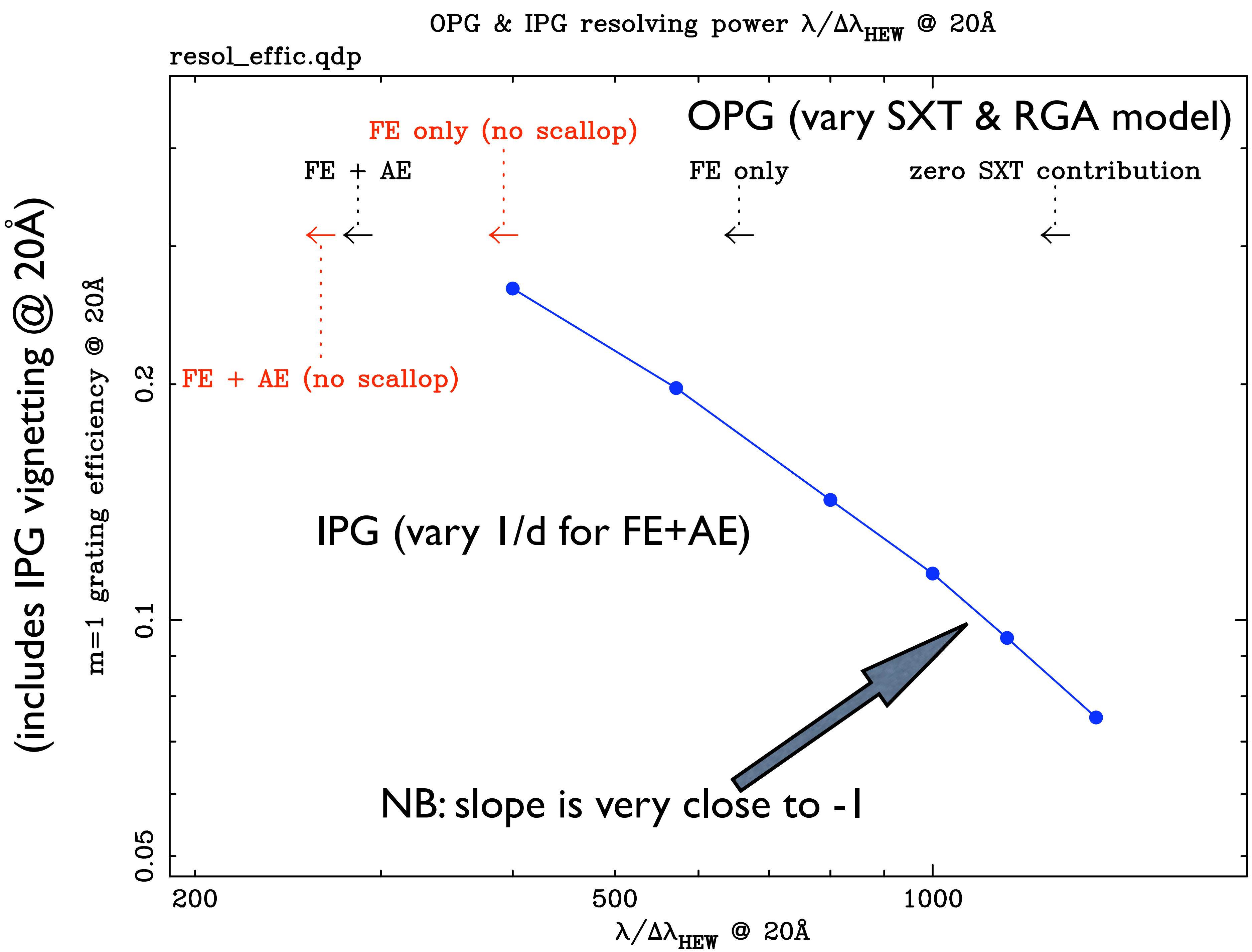
15” HPD “FE+AE” SXT



No scalloping– $\Delta\lambda_{HEW}$: 51→76mÅ

(for zero grating misalignments)

Summary of the resolving power calculations (OPG & IPG)



Conclusions:

- We have modelled RGS spectral resolving power for both IPG and OPG designs for grating test rulings that exist, with measured efficiencies (cf. SPIE 5168-28, Rasmussen et al.)

- It is possible to improve the spectral resolution for the IPG RGS by increasing ruling density and facet blaze angle. The combination of narrower grooves and larger degree of vignetting result in a lower effective area, with effective area nearly inversely proportional to resolving power at 20Å.

- The OPG option was suggested as a solution that could simultaneously provide vastly superior spectral resolution and effective area. We have not been able to confirm those projections (these predictions are roughly ***a factor of 5*** worse than Cash's) and we suggest that the predicted OPG resolving power depends sensitively on assumptions of the SXT PSF internal structure.

- A ***robust*** instrument model for the OPG RGS is more meaningful than an ***optimistic*** one.

end

(backup OPG resolving power slide)

OPG Resolving power dependence on scallop radius for 20Å: